EXHIBIT M

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Std 802.1D-1990

IEEE Standards for Local and Metropolitan Area Networks:

Media Access Control (MAC) Bridges

Sponsor

Technical Committee on Computer Communications
of the
IEEE Computer Society

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Abstract: IEEE 802.1D-1990, *IEEE Standards for Local and Metropolitan Area Networks: Media Access Control (MAC) Bridges*, defines an architecture for the interconnection of IEEE 802 Local Area Networks (LANs) below the level of the MAC Service, transparent to LLC and higher layer protocols. The operation and management of the connecting Bridges is specified. A Spanning Tree Algorithm and Protocol ensures a loop-free topology and provides redundancy. The Bridging method is not particular to any MAC type—criteria for additional MAC-specific Bridging methods are defined.

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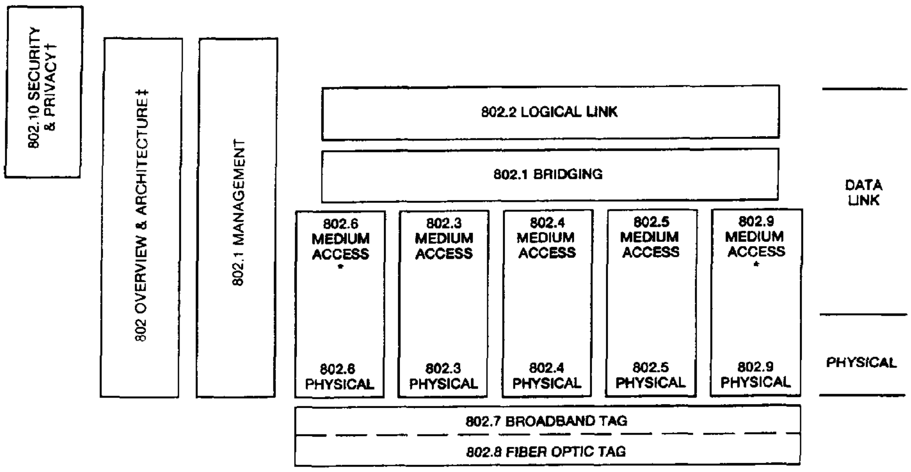
Foreword

(This Foreword is not a part of IEEE Std 802.1D-1990, IEEE Standards for Local and Metropolitan Area Networks: Media Access Control (MAC) Bridges.)

This standard is part of a family of standards for Local and Metropolitan Area Networks. The relationship between this standard and other members of the family is shown below. (The numbers in the figure refer to IEEE Standard numbers.)



* 802.6 and 802.9 provide services beyond the scope of IEEE Project 802.
† 802.10 is co-sponsored by the Technical Committee on Computer Communications (which sponsors Project 802) and also the Technical Committee on Security and Privacy.
‡ Formerly IEEE Std 802.1A.

Relationship Among IEEE Project 802 Working Groups and Technical Advisory Groups

The family of IEEE 802 Standards includes publications, projects, and activities that define standards, recommended practices, and guidelines in the following areas:

- IEEE Std 802*: Overview and Architecture. This document forms part of the 802.1 scope of work.

*The 802 Architecture and Overview Specification, originally known as IEEE Std 802.1A, has been renumbered as IEEE Std 802. This has been done to accommodate recognition of the base standard in a family of standards. References to IEEE Std 802.1A should be considered as references to IEEE Std 802.

• IEEE 802.1 series:	Glossary, Network Management, and Internetworking. These documents, as well as IEEE Std 802, Overview and Architecture, form part of the 802.1 scope of work.
• ISO 8802-2 [ANSI/IEEE Std 802.2]:	Logical Link Control
• ISO/IEC 8802-3 [ANSI/IEEE Std 802.3]:	CSMA/CD Access Method and Physical Layer Specifications
• ISO/IEC 8802-4 [ANSI/IEEE Std 802.4]:	Token-Passing Bus Access Method and Physical Layer Specifications
• IEEE Std 802.5:	Token-Passing Ring Access Method and Physical Layer Specifications
• P802.6:	Metropolitan Area Network Access Method and Physical Layer Specifications
• IEEE Std 802.7:	Broadband Technical Advisory and Physical Layer Topics and Recommended Practices
• P802.8:	Fiber Optic Technical Advisory and Physical Layer Topics
• P802.9:	Integrated Voice/Data Access Method and Physical Layer Specifications
• P802.10:	Security and Privary Access Method and Physcial Layer Specifications
• P802.11:	Wireless Access Method and Physical Layer Specification (activity on this project began as this document went to press)

This document, IEEE Std 802.1D, specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.

The reader of this document is urged to become familiar with the complete family of standards.

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4. The Spanning Tree Algorithm and Protocol

The configuration algorithm and protocol described in this section reduce the Bridged Local Area Network topology to a single Spanning Tree.

4.1 Requirements to be Met by the Algorithm. The Spanning Tree Algorithm and its associated Bridge Protocol operate to Support, Preserve, and Maintain the Quality of the MAC Service in all its aspects as discussed in Section 2. In order to perform this function, the algorithm meets the following requirements, each of which is related to the discussion in that section:

(1) It will configure the active topology of a Bridged Local Area Network of arbitrary topology into a single spanning tree, such that there is at most one data route between any two end stations, eliminating data loops (2.3.3; 2.3.4).

(2) It will provide for fault tolerance by automatic reconfiguration of the spanning tree topology as a result of Bridge failure or a breakdown in a data path, within the confines of the available Bridged Local Area Network components, and for the automatic accommodation of any Bridge or Bridge Port added to the Bridged Local Area Network without the formation of transient data loops (2.1).

(3) The entire active topology will stabilize in any sized Bridged Local Area Network. It will, with a high probability, stabilize within a short, known bounded interval in order to minimize the time for which the service is unavailable for communication between any pair of end stations (2.1).

(4) The active topology will be predictable and reproducible, and may be selected by management of the parameters of the algorithm, thus allowing the application of Configuration Management, following traffic analysis, to meet the goals of Performance Management (2.1; 2.3.10).

(5) It will operate transparently to the end stations, such that they are unaware of their attachment to a single LAN or a Bridged Local Area Network when using the MAC Service (2.2).

(6) The communications bandwidth consumed by the Bridges in establishing and maintaining the spanning tree on any particular LAN will be a small percentage of the total available bandwidth and independent of the total traffic supported by the Bridged Local Area Network regardless of the total number of Bridges or LANs (2.3.10).

Additionally, the algorithm and protocol meet the following goals which limit the complexity of Bridges and their configuration:

(a) The memory requirements associated with each Bridge Port are independent of the number of Bridges and LANs in the Bridged Local Area Network.
(b) Bridges do not have to be individually configured before being added to the Bridged Local Area Network, other than having their MAC addresses assigned through normal procedures.

4.2 Requirements of the MAC Bridges. In order for the Bridge Protocol to operate, the following are required:

(1) A unique MAC group address, recognized by all the Bridges within the Bridged Local Area Network, that identifies the Bridge Protocol Entities of all Bridges attached to an individual LAN.
(2) An identifier for each Bridge, unique within the Bridged Local Area Network.
(3) A distinct Port identifier for each Bridge Port, that can be assigned independently of the values used in other Bridges.

Values for each of these parameters, or a mechanism for assigning values to them, shall be provided by each Bridge. In the case of MAC Bridges that use 48-bit Universally Administered Addresses, the unique MAC Address that identifies the Bridge Protocol Entities is the Bridge Group Address (3.12.3).

In addition, to allow the configuration of the Spanning Tree active topology to be managed, the following are required:

(a) A means of assigning the relative priority of each Bridge within the set of Bridges in the Bridged Local Area Network.
(b) A means of assigning the relative priority of each Port within the set of Ports of an individual Bridge.
(c) A means of assigning a path cost component to each Port.

These parameters may be set by management.

The unique identifier for each Bridge is derived, in part, from the Bridge Address (3.12.5) and, in part, from a manageable priority component (5.2.5). The relative priority of Bridges is determined by the numerical comparison of the unique identifiers, with the lower numerical value indicating the higher priority identifier.

Part of the identifier for each Port is fixed and is different for each Port on a Bridge, and part is a manageable priority component (5.2.7). The relative priority of Ports is determined by the numerical comparison of the unique identifiers, with the lower numerical value indicating the higher priority identifier.

The path cost associated with each Port may be manageable. Additionally, 4.10.2 recommends default values for Ports attached to LANs of specific MAC types and speeds.

4.3 Overview

4.3.1 The Active Topology and Its Computation. The Spanning Tree Algorithm and Protocol configure a simply connected active topology from the arbitrarily connected components of a Bridged Local Area Network. Frames are forwarded through some of the Bridge Ports in the Bridged Local Area Network and not

through others, which are held in a blocking state. At any time, Bridges effectively connect just the LANs to which Ports in a forwarding state are attached. Frames are forwarded in both directions through Bridge Ports that are in a forwarding state. Ports that are in a blocking state do not forward frames in either direction but may be included in the active topology, i.e., be put into a forwarding state if components fail, are removed, or are added.

Figure 2-2 shows an example of a Bridged Local Area Network. Figure 4-1 shows the active topology, i.e., the logical connectivity, of the same Bridged Local Area Network following configuration.

One of the Bridges is known as the Root or the Root Bridge in the Bridged Local Area Network. Each individual LAN has a Bridge Port connected to it that forwards frames from that LAN towards the Root and forwards frames from the direction of the Root onto that LAN. This Port is known as the Designated Port for that LAN, and the Bridge of which it is part is the Designated Bridge for the LAN. The Root is the Designated Bridge for all the LANs to which it is connected. The Ports on each Bridge that are in a forwarding state are the Root Port (that closest to the Root—see below) and the Designated Ports (if there are any).

In Fig 4-1, Bridge 1 has been selected as the Root (though one cannot tell simply by looking at the topology which Bridge is the Root) and is the Designated Bridge for LAN 1 and LAN 2. Bridge 2 is the Designated Bridge for LAN 3 and LAN 4, and Bridge 4 is the Designated Bridge for LAN 5. Figure 4-2 shows the logical tree topology of this configuration of the Bridged Local Area Network.

The stable active topology of a Bridged Local Area Network is determined by

(1) The unique Bridge Identifiers associated with each Bridge.
(2) The Path Cost associated with each Bridge Port.
(3) The Port Identifier associated with each Bridge Port

The Bridge with the highest priority Bridge Identifier is the Root (for convenience of calculation this is the identifier with the lowest numerical value). Every Bridge Port in the Bridged Local Area Network has a Root Path Cost associated with it. This is the sum of the Path Costs for each Bridge Port receiving frames forwarded from the Root on the least cost path to the Bridge. The Designated Port for each LAN is the Bridge Port for which the value of the Root Path Cost is the lowest: if two or more Ports have the same value of Root Path Cost, then first the Bridge Identifier of their Bridges and then their Port Identifiers are used as tie-breakers. Thus, a single Bridge Port is selected as the Designated Port for each LAN, the same computation selects the Root Port of a Bridge from amongst the Bridge's own Ports, and the active topology of the Bridged Local Area Network is completely determined.

A component of the Bridge Identifier of each Bridge, and the Path Cost and Port Identifier of each Bridge Port, can be managed, thus allowing a manager to select the active topology of the Bridged Local Area Network.

4.3.2 Propagating the Topology Information. Bridges send a type of Bridge Protocol Data Unit known as a Configuration BPDU to each other in order to communicate and compute the above information. A MAC frame conveying a BPDU carries the Bridge Group Address in the destination address field and is received by all the Bridges connected to the LAN on which the frame is transmitted.

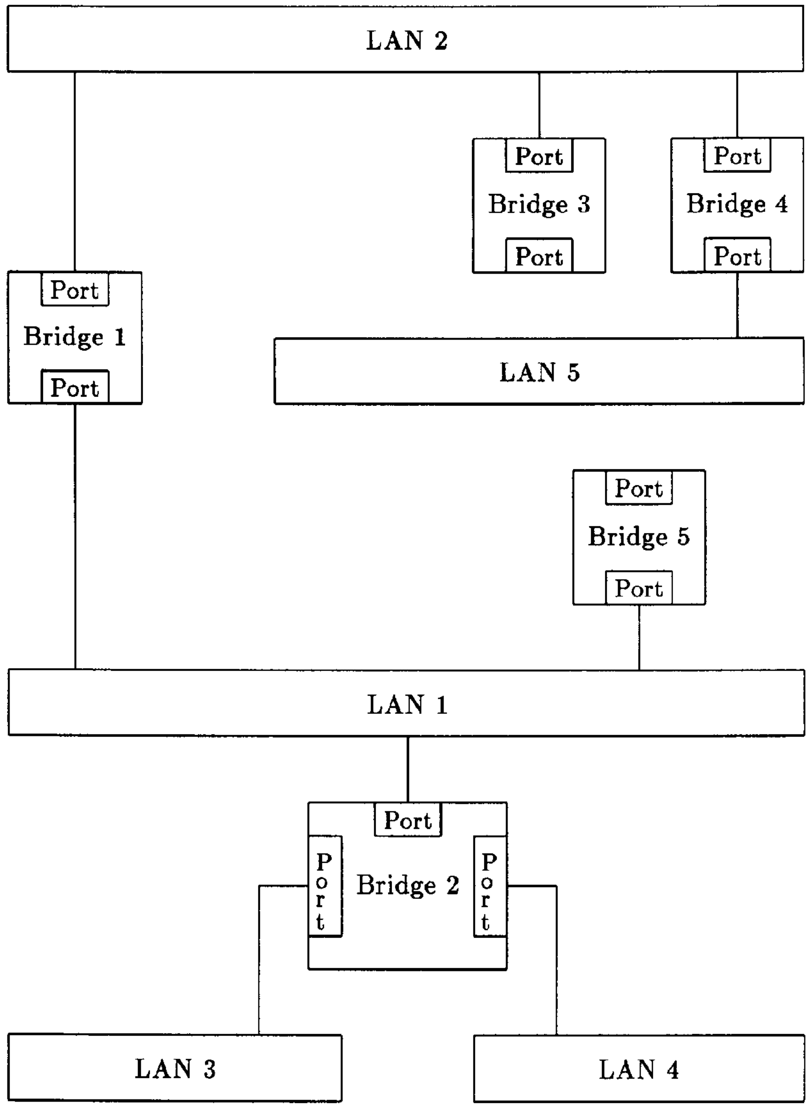


Fig 4-1
Active Topology

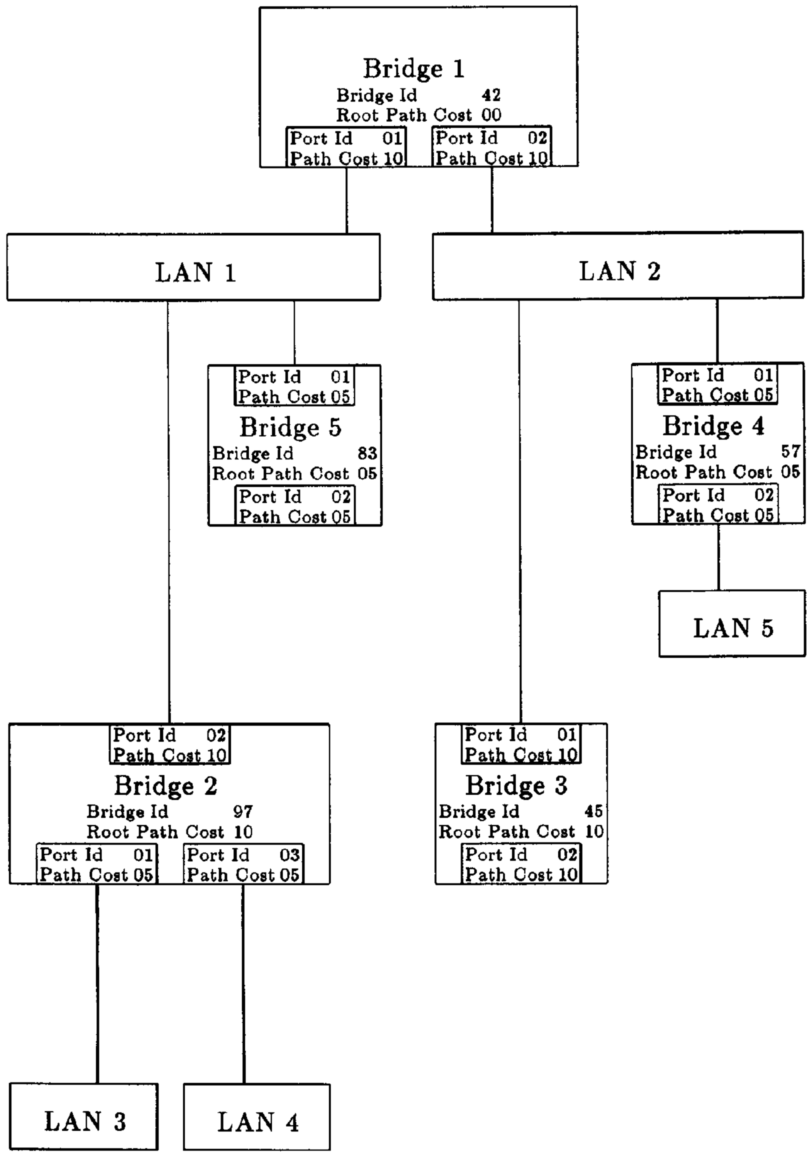


Fig 4-2
Spanning Tree

Bridge Protocol Data Units are not directly forwarded by Bridges, but the information in them may be used by a Bridge in calculating its own BPDU to transmit, and may stimulate that transmission. The Configuration BPDU, which is conveyed between the Bridge Ports attached to a single LAN, is distinguished from the notion of a Configuration Message, which expresses the propagation of the information carried throughout the Bridged Local Area Network.

Each Configuration BPDU contains, among other parameters, the unique identifier of the Bridge that the transmitting Bridge believes to be the Root, the cost of the path to the Root from the transmitting Port, the identifier of the transmitting Bridge, and the identifier of the transmitting Port. This information is sufficient to allow a receiving Bridge to determine whether the transmitting Port has a better claim to be the Designated Port on the LAN on which the Configuration BPDU was received than the Port currently believed to be the Designated Port, and to determine whether the receiving Port should become the Root Port for the Bridge if it is not already.

Timely propagation throughout the Bridged Local Area Network of the necessary information to allow all Bridge Ports to determine their state (blocking or forwarding) is achieved through three basic mechanisms:

(1) A Bridge that believes itself to be the Root (all Bridges start by believing themselves to be the Root until they discover otherwise); originates Configuration Messages (by transmitting Configuration BPDUs) on all the LANs to which it is attached, at regular intervals.

(2) A Bridge that receives a Configuration BPDU on what it decides is its Root Port conveying better information (i.e., highest priority Root Identifier, lowest Root Path Cost, highest priority transmitting Bridge and Port), passes that information on to all the LANs for which it believes itself to be the Designated Port.

(3) A Bridge that receives inferior information on a Port it considers to be the Designated Port on the LAN to which it is attached, transmits its own information in reply for all other Bridges attached to that LAN to hear.

Hence, Spanning Tree paths to the Bridge with highest priority Root Identifier are quickly learned throughout the Bridged Local Area Network, with inferior information about other potential roots and paths being contradicted.

4.3.3 Reconfiguration. To allow for reconfiguration of the Bridged Local Area Network when components are removed or when management changes are made to parameters determining the topology, the topology information propagated throughout the Bridged Local Area Network has a limited lifetime. This is effected by transmitting the age of the information conveyed (the time elapsed since the Configuration Message originated from the Root) in each Configuration BPDU. Every Bridge stores the information from the Designated Port on each of the LANs to which its Ports are connected, and monitors the age of that information.

In normal stable operation, the regular transmission of Configuration Messages by the Root ensures that topology information is not timed out.

If the Bridge times out the information held for a Port, it will attempt to become the Designated Port for the LAN to which that Port is attached, and will transmit protocol information received from the Root on its Root Port on to that LAN.

If the Root Port of the Bridge is timed out, then another Port may be selected as the Root Port. The information transmitted on LANs for which the Bridge is the Designated Bridge will then be calculated on the basis of information received on the new Root Port.

If no record of information from the current Root remains, then the Bridge will reconfigure by claiming to be the Root itself. If the Root has indeed failed, other Bridges will also be timing out protocol information; information as to the best successor and the new topology will rapidly propagate throughout the Bridged Local Area Network. It is also possible that the path to the current Root has changed, perhaps by increasing in cost, and that the reconfiguring Bridge has timed out because it considered more recent information from the Root inferior since it had a higher Root Path Cost. In this latter case, neighboring Bridges will immediately reply to BPDUs transmitted by the aspiring Root.

To ensure that all Bridges in the Bridged Local Area Network share a common understanding of when old information should be timed out, the timeout value is transmitted in all Configuration Messages from the Root. This value takes account of the propagation delays in transmitting and receiving BPDUs on each of the LANs in the Bridged Local Area Network, and thus of propagation of protocol information down the Spanning Tree. To minimize the probability of triggering reconfiguration through the loss of Configuration Messages, it includes an additional multiple of the time interval at which these are transmitted by the Root.

4.3.4 Changing Port State. Since there are propagation delays in passing protocol information throughout a Bridged Local Area Network, there cannot be a sharp transition from one active topology to another. Topology changes may take place at different times in different parts of the Bridged Local Area Network and to move a Bridge Port directly from non-participation in the active topology to the forwarding state would be to risk having temporary data loops and the duplication and misordering of frames. It is also desirable to allow other Bridges time to reply to inferior protocol information before starting to forward frames.

Bridge Ports must therefore wait for new topology information to propagate throughout the Bridged Local Area Network, and for the frame lifetime of any frames forwarded using the old active topology to expire, before forwarding frames.

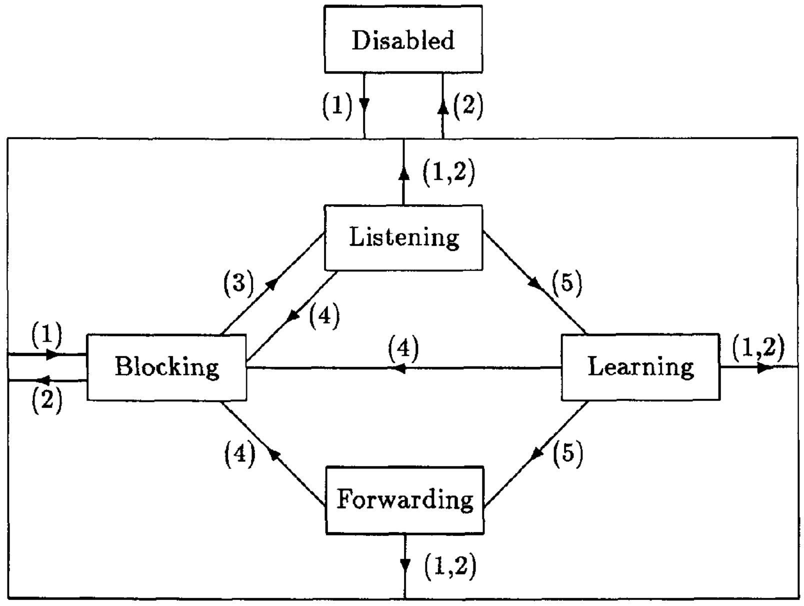
During this time it is also desirable to time out station location information in the Filtering Database that may no longer be true and, during the latter part of this interval, to learn new station location information in order to minimize the effect of initial flooding of frames when the Port enters a forwarding state. When the algorithm decides that a Port should be put into the Forwarding State, it is, therefore, first put into a Listening State where it waits for protocol information that suggests it should return to the Blocking State, and for the expiry of a protocol timer that would move it into a Learning State. In the Learning State, it still blocks the forwarding of frames, but learned station location information is included by the Learning Process in the Filtering Database. Finally the expiry of a protocol timer moves it into the Forwarding State where both forwarding of relayed frames and learning of station location information are enabled.

Figure 4-3 shows the transitions between the Port States.

4.3.5 Notifying Topology Changes. In normal stable operation, station location information in the Filtering Database need only change as a consequence of the physical relocation of stations. It may, therefore, be desirable to employ a long ageing time for entries in the Filtering Database, especially as many end stations transmit frames following power-up after relocation which would cause station location information to be relearned.

However, when the active topology of a Bridged Local Area Network reconfigures, end stations may appear to move from the point of view of a Bridge in the network. This is true even if the states of the Ports on that Bridge have not changed. It is necessary for station location to be relearned following a change in the active topology, even if only part of the Bridged Local Area Network has reconfigured.

Fig 4-3
Port States



(1) Port enabled, by management or initialization
(2) Port disabled, by management or failure
(3) Algorithm selects as Designated or Root Port
(4) Algorithm selects as not Designated or Root Port
(5) Protocol timer expiry (Forwarding Timer)

The Spanning Tree Algorithm and Protocol provide procedures for a Bridge which detects a change in active topology to notify the Root of the change reliably, and for the Root subsequently to communicate the change to all the Bridges. The Bridges then use a short value to ageout dynamic entries in the Fitering Database for a period.

When a Bridge that is not the Root changes the active topology of the Bridged Local Area Network, it transmits a Topology Change Notification BPDU on the LAN to which its Root Port is attached. This transmission is repeated until the Bridge receives an acknowledgment from the Designated Bridge for that LAN. The acknowledgment is carried in a Configuration BPDU, thus the notification will eventually be acknowledged or further reconfiguration will take place. The Designated Bridge passes the notification to, or towards, the Root using the same procedure.

If the Root receives such a notification, or changes the topology itself, it will set a Topology Change flag in all Configuration Messages transmitted for some time. This time is such that all Bridges will receive one or more of the Configuration Messages, or further reconfiguration will take place. While this flag is set, Bridges use the value of Forwarding Delay (the time interval spent in each of the Listening and Learning States) to age out dynamic entries. When the flag is reset again, Bridges revert to using the Filtering Database Ageing Time.

4.4 Port States. The operation of an individual Bridge Port is described in terms of the State of the Port and the Processes (3.3) that provide and support the functions necessary for the operation of the Bridge (3.1).

The State of each Port governs the processing of frames received from the individual MAC Entity associated with the Port (3.5), the submission of frames to the MAC Entity for transmission (3.6), and the possible inclusion of the Port in the active topology of the Bridged Local Area Network.

The operation of the Spanning Tree Algorithm and Protocol serves to maintain and change the State of each Port in order to meet the requirements placed on the algorithm (4.1). The possible Port States and the associated rules relating to the processing of frames are particular to this algorithm and Bridge Protocol.

The following are specified below for each of the five States — Blocking, Listening, Learning, Forwarding, or Disabled — that a Port may be in:

(1) The purpose of the State.
(2) Whether the Forwarding Process (3.7) discards received frames.
(3) Whether the Forwarding Process (3.7) submits forwarded frames for transmission.
(4) How the Learning Process (3.8) processes received frames.
(5) Whether the Bridge Protocol Entity (3.10) includes the Port in its computation of the active topology.
(6) Under which conditions a Port enters and leaves the State.

4.4.1 Blocking. A Port in this State does not participate in frame relay, thus preventing frame duplication arising through multiple paths existing in the active topology of the Bridged Local Area Network.

The Forwarding Process shall discard received frames. It shall not submit forwarded frames for transmission. The Learning Process shall not add station location information to the Filtering Database.

The Bridge Protocol Entity shall include the Port in its computation of the active topology. BPDUs received shall be processed as required by the Spanning Tree Algorithm and Protocol.

This State is entered following initialization of the Bridge or from the Disabled State when the Port is enabled through the operation of management. This State may be entered from the Listening, Learning, or Forwarding States through the operation of the Spanning Tree Algorithm and Protocol. A Port enters the Blocking State because it has received information that another Bridge is the Designated Bridge for the LAN to which the Port is attached.

This State may be left upon expiry of a protocol timer or receipt of a Configuration BPDU on this or another Port, and the Listening State entered, through the operation of the Spanning Tree Algorithm and Protocol. This State may be left, and the Disabled State entered, through management action.

4.4.2 Listening. A Port in this State is preparing to participate in frame relay. Frame relay is temporarily disabled in order to prevent temporary loops, which may occur in a Bridged Local Area Network during the lifetime of this State as the active topology of the Bridged Local Area Network changes. Learning is disabled since changes in active topology may lead to the information acquired being incorrect when the active topology becomes stable.

The Forwarding Process shall discard received frames. It shall not submit forwarded frames for transmission. The Learning Process shall not add station location information to the Filtering Database.

The Bridge Protocol Entity shall include the Port in its computation of the active topology. BPDUs received shall be processed as required by the Spanning Tree Algorithm and Protocol. BPDUs can be submitted for transmission.

This State is entered from the Blocking State when the operation of the Spanning Tree Algorithm and Protocol determines that the Port should participate in frame relay.

This State may be left upon the expiry of a protocol timer, and the Learning State entered, through the operation of the Spanning Tree Algorithm and Protocol. This State may be left upon receipt of a Bridge Protocol Data Unit on this or another Port, and the Blocking State entered, through the operation of the Spanning Tree Algorithm and Protocol. This State may be left, and the Disabled or the Blocking State entered, through management action.

4.4.3 Learning. A Port in this State is preparing to participate in frame relay. Frame relay is temporarily disabled in order to prevent temporary loops, which may occur in a Bridged Local Area Network during the lifetime of this State as the active topology of the Bridged Local Area Network changes. Learning is enabled to allow information to be acquired prior to frame relay in order to reduce the number of frames unnecessarily relayed.

The Forwarding Process shall discard received frames. It shall not submit forwarded frames for transmission. The Learning Process shall incorporate station location information into the Filtering Database.

The Bridge Protocol Entity shall include the Port in its computation of the active topology. BPDUs received shall be processed as required by the Spanning Tree Algorithm and Protocol. BPDUs can be submitted for transmission.

This State is entered from the Listening State through the operation of the Spanning Tree Algorithm and Protocol, on the expiry of a protocol timer.

This State may be left upon the expiry of a protocol timer, and the Forwarding State entered, through the operation of the Spanning Tree Algorithm and Protocol. This State may be left upon receipt of a Bridge Protocol Data Unit on this or another Port, and the Blocking State entered, through the operation of the Spanning Tree Algorithm and Protocol. This State may be left, and the Disabled or the Blocking State entered, through management action.

4.4.4 Forwarding. A Port in this State is participating in frame relay.

The Forwarding Process can forward received frames. It can submit forwarded frames for transmission. The Learning Process shall incorporate station location information into the Filtering Database.

The Bridge Protocol Entity shall include the Port in its computation of the active topology. BPDUs received shall be processed as required by the Spanning Tree Algorithm and Protocol. BPDUs can be submitted for transmission.

This State is entered from the Learning State through the operation of the Spanning Tree Algorithm and Protocol, on the expiry of a protocol timer.

This State may be left upon receipt of a Bridge Protocol Data Unit on this or another Port, and the Blocking State entered, through the operation of the Spanning Tree Algorithm and Protocol. This State may be left, and the Disabled or the Blocking State entered, through management action.

4.4.5 Disabled. A Port in this State does not participate in frame relay or the operation of the Spanning Tree Algorithm and Protocol.

The Forwarding Process shall discard received frames. It shall not submit forwarded frames for transmission. The Learning Process shall not incorporate station location information into the Filtering Database.

The Bridge Protocol Entity shall not include the Port in its computation of the active topology. BPDUs received shall not be processed by the Spanning Tree Algorithm and Protocol. BPDUs shall not be submitted for transmission.

This State is entered from any other State by the operation of management.

This State is left when the Port is enabled by management action, and the Blocking State is entered.

4.5 Protocol Parameters and Timers. Information is transferred between the Protocol Entities of individual Bridges by the exchange of Bridge Protocol Data Units. This section specifies the parameters conveyed in the two types of BPDU specified: Configuration BPDUs and Topology Change Notification BPDUs. The encoding of these parameters and additional information elements are specified in Section 5.

Each Bridge Protocol Entity maintains a number of parameters and timers independently of the individual Ports, and a number of timers and parameters for each Port. This section specifies those parameters, their use, and under what conditions they are updated.

4.5.1 Configuration BPDU Parameters

4.5.1.1 Root Identifier. The unique Bridge Identifier of the Bridge assumed to be the Root by the Bridge transmitting the Configuration BPDU.

This parameter is conveyed to enable all Bridges to agree on the Root.

4.5.1.2 Root Path Cost. The Cost of the path to the Root Bridge denoted by the Root Identifier from the transmitting Bridge.

This parameter is conveyed to enable a Bridge to decide which of the Bridges attached to the LAN on which the Configuration BPDU has been received offers the lowest Cost path to the Root for that LAN.

4.5.1.3 Bridge Identifier. The unique Bridge Identifier of the Bridge transmitting the Configuration BPDU.

This parameter is conveyed to enable a Bridge to

(1) Decide, in the case of a LAN to which two or more Bridges are attached, which offer equal Cost paths to the Root, which of the Bridges should be selected as the Designated Bridge for that LAN.

(2) Detect the case where two or more Ports on the same Bridge are attached to the same LAN, i.e., are in direct communication through a path of Bridged Local Area Network components none of which operate the Spanning Tree Algorithm and Protocol.

4.5.1.4 Port Identifier. The Port Identifier of the Port on the transmitting Bridge through which the Configuration BPDU was transmitted. This identifier uniquely identifies a Port on that Bridge.

This parameter is conveyed to enable a Bridge to decide, in the case of a LAN to which two or more Ports on the same Bridge are attached, which Ports are so attached.

4.5.1.5 Message Age. The age of the Configuration Message, being the time since the generation of the Configuration BPDU by the Root that instigated the generation of this Configuration BPDU.

This parameter is conveyed to enable a Bridge to discard information whose age exceeds Max Age (see below).

4.5.1.6 Max Age. A timeout value to be used by all Bridges in the Bridged Local Area Network. The value of Max Age is set by the Root.

This parameter is conveyed to ensure that each Bridge in a Bridged Local Area Network has a consistent value against which to test the age of stored configuration information.

4.5.1.7 Hello Time. The time interval between the generation of Configuration BPDUs by the Root.

This parameter is not directly used by the Spanning Tree Algorithm but is conveyed in Configuration BPDUs to facilitate the monitoring of protocol performance by management functions.

4.5.1.8 Forward Delay. A timeout value to be used by all Bridges in the Bridged Local Area Network. The value of Forward Delay is set by the Root.

This parameter is conveyed to ensure that each Bridge in a Bridged Local Area Network uses a consistent value for the Forward Delay Timer when transferring the State of a Port to the Forwarding State. This parameter is also used as the

timeout value for ageing Filtering Database dynamic entries following changes in active topology.

4.5.1.9 Topology Change Acknowledgment. A flag set by a Bridge which is the Designated Bridge for a LAN and which is transmitting a Configuration BPDU in response to a received Topology Change Notification BPDU.

This parameter is conveyed to allow a reliable acknowledged protocol to operate for the purpose of notifying the Root of changes in active topology.

4.5.1.10 Topology Change. A flag set by the Root in all Configuration BPDUs transmitted for a period of time following the notification or detection of a topology change.

This parameter is conveyed to notify Bridges throughout the Bridged Local Area Network that there has been a change in active topology in part of the Bridged Local Area Network and that the Filtering Database should age out entries more quickly in order to limit the effects of temporary isolation of end systems attached to the Bridged Local Area Network brought about by the use of incorrect information in the Filtering Database.

The value of the ageing time applied to dynamic entries in the Filtering Database becomes equal to that of the value of the Forward Delay time parameter held for the Bridge; i.e., after Forward Delay time has elapsed while the Topology Change flag is set in all Configuration Messages received from the Root, then the only dynamic entries remaining in the Filtering Database are those that have been created or updated during that period.

4.5.2 Topology Change Notification BPDU Parameters. No parameters are conveyed in a Topology Change Notification BPDU.

4.5.3 Bridge Parameters

4.5.3.1 Designated Root. The unique Bridge Identifier of the Bridge assumed to be the Root.

This parameter is used as the value of the Root Identifier parameter in all Configuration BPDUs transmitted by the Bridge.

4.5.3.2 Root Path Cost. The Cost of the path to the Root from this Bridge. It is equal to the sum of the values of the Designated Cost and Path Cost parameters held for the Root Port. When the Bridge is the Root this parameter has the value zero.

This parameter is used

(1) To test the value of the Root Path Cost parameter conveyed in received Configuration BPDUs.

(2) As the value of the Root Path Cost parameter offered in all Configuration BPDUs transmitted by the Bridge.

4.5.3.3 Root Port. The Port Identifier of the Port that offers the lowest cost path to the Root, i.e., that Port for which the sum of the values of the Designated Cost and Path Cost parameters held for the Port is the lowest.

If two or more Ports offer equal least cost paths to the Root, the Root Port is selected to be that with the highest priority Bridge Identifier held as the Designated Bridge Parameter for that Port.

If two or more Ports offer equal least cost paths to the Root and hold the same Designated Bridge parameter values, then the Root Port is selected to be that with

the highest priority Designated Port held for that Port.

Finally, if two or more ports offer equal least cost paths to the Root and hold the same Designated Bridge and Designated Port parameter values, then the Root Port is selected to be that with the highest priority Port Identifier. The Port Identifiers for different Ports on the same Bridge are guaranteed to be different and thus enforce a tie-breaker.

This parameter is used to identify the Port through which the path to the Root is established. It is not significant when the Bridge is the Root, and is set to zero.

4.5.3.4 Max Age. The maximum age of received protocol information before it is discarded.

4.5.3.5 Hello Time. The time interval between the transmission of Configuration BPDUs by a Bridge that is attempting to become the Root or is the Root.

4.5.3.6 Forward Delay. The time spent in the Listening State while moving from the Blocking State to the Learning State.

The time spent in the Learning State while moving from the Listening State to the Forwarding State.

The value used for the ageing time of dynamic entries in the Filtering Database while the Topology Change flag is set in protocol messages received from the Root.

4.5.3.7 Bridge Identifier. The unique Bridge Identifier of the Bridge.

This parameter is used as the value of

(1) The Bridge Identifier parameter in all Configuration BPDUs transmitted by the Bridge.

(2) The Bridge's Designated Root when the Bridge is the Root, or when the Bridge attempts to become the Root, following expiry of all information concerning the current Root, or following management action.

This parameter comprises two parts, one of which is derived from the unique Bridge Address (3.12.5) and assures the uniqueness of the Bridge Identifier in the Bridged Local Area Network, the other of which allows the adjustment of the priority of the Bridge Identifier and is taken as the more significant part in priority comparisons. The priority part of this parameter may be updated by management action.

4.5.3.8 Bridge Max Age. The value of the Max Age parameter when the Bridge is the Root or is attempting to become the Root.

This parameter may be updated by management action.

4.5.3.9 Bridge Hello Time. The value of the Hello Time parameter when the Bridge is the Root or is attempting to become the Root.

The time interval between transmissions of Topology Change Notification BPDUs towards the Root when the Bridge is attempting to notify the Designated Bridge on the LAN to which its Root Port is attached of a topology change.

This parameter may be updated by management action.

4.5.3.10 Bridge Forward Delay. The value of the Forward Delay parameter when the Bridge is the Root or is attempting to become the Root.

This parameter may be updated by management action.

4.5.3.11 Topology Change Detected. A Boolean parameter set True to record a topology change that has been detected by or notified to the Bridge.

This parameter is used

(1) To stimulate regular transmissions, at intervals determined by the Bridge Hello Time, of a Topology Change Notification BPDU towards the Root where the Bridge itself is not the Root.

(2) If True, to set the value of the Topology Change parameter for the Bridge True if the Bridge is, or becomes, the Root.

4.5.3.12 Topology Change. A Boolean parameter set to record the value of the Topology Change flag in Configuration BPDUs to be transmitted by the Bridge on LANs for which the Bridge is the Designated Bridge.

If the value of this parameter is True, the timeout value of the Filtering Database ageing timer is equal to the value of the Forward Delay parameter. Dynamic entries whose age is greater than this value are removed from the Filtering Database.

If the value of this parameter is False, the timeout value of the Filtering Database ageing timer is equal to the value of the Ageing Time. Ageing Time may be set by management (Section 6).

4.5.3.13 Topology Change Time. The time period for which Bridge Protocol Data Units are transmitted with the Topology Change flag set by the Bridge when it is the Root following the detection of a topology change.

This value of this parameter is equal to the sum of the Bridge's Bridge Max Age and Bridge Forward Delay parameters. Either of these parameters may be updated by management action.

4.5.3.14 Hold Time. This parameter specifies the minimum time period elapsing between the transmission of Configuration BPDUs through a given Bridge Port. No more than two Configuration BPDUs shall be transmitted in any Hold Time time period.

This parameter is a fixed parameter of the Bridge. Its value is specified in Table 4-3.

4.5.4 Bridge Timers

4.5.4.1 Hello Timer. This timer serves to ensure periodic transmission of Configuration BPDUs by the Bridge when it is, or is attempting to become, the Root.

The timeout value of the timer is determined by the Bridge's Bridge Hello Time parameter.

4.5.4.2 Topology Change Notification Timer. This timer serves to ensure that the Designated Bridge on the LAN to which the Bridge's Root Port is attached is notified of any detected topology change.

The timeout value of the timer is determined by the Bridge's Bridge Hello Time parameter.

4.5.4.3 Topology Change Timer. This timer serves to determine the time period for which Configuration BPDUs are transmitted with the Topology Change flag set by the Bridge when it is the Root following the detection of a topology change.

The timeout value of the timer is determined by the Bridge's Topology Change Time parameter.

4.5.5 Port Parameters

4.5.5.1 Port Identifier. The Port Identifier of the associated Port.

This parameter is used as the value of the Port Identifier parameter of all Configuration BPDUs transmitted on the associated Port.

This parameter comprises two parts. One part bears a fixed relationship to the physical Ports supported by the real world equipment. Ports are identified by small integers from one upwards. This part of the parameter assures the uniqueness of the Port Identifier among the Ports of a single Bridge. The other part of the parameter allows the adjustment of the priority of the Port and is taken as the more significant part in priority comparisons. The priority part of this parameter may be updated by management action.

4.5.5.2 State. The current State of the Port (i.e., Disabled, Listening, Learning, Forwarding, or Blocking).

This parameter is used to control the acceptance of frames from the MAC Entity associated with the Port by the Forwarding and Learning Processes, the forwarding of frames by the Forwarding Process to that MAC Entity, and the transmission and reception of BPDUs (4.4).

This parameter is updated by the action of the protocol.

This parameter may also be updated by management action.

4.5.5.3 Path Cost. The contribution of the path through this Port, when the Port is the Root Port, to the total cost of the path to the Root for this Bridge.

This parameter is used, added to the value of the Designated Cost parameter for the Root Port, as the value of the Root Path Cost parameter offered in all Configuration BPDUs transmitted by the Bridge, when it is not the Root.

This parameter may be updated by management action.

4.5.5.4 Designated Root. The unique Bridge Identifier of the Bridge recorded as the Root in the Root Identifier parameter of Configuration BPDUs transmitted by the Designated Bridge for the LAN to which the Port is attached.

This parameter is used to test the value of the Root Identifier parameter conveyed in received Configuration BPDUs.

4.5.5.5 Designated Cost. The cost of the path to the Root offered by the Designated Port on the LAN to which this Port is attached.

This parameter is used to test the value of the Root Path Cost parameter conveyed in received Configuration BPDUs.

4.5.5.6 Designated Bridge. The unique Bridge Identifier of the Bridge believed to be the Designated Bridge for the LAN associated with the Port.

This parameter is used

(1) Together with the Designated Port and Port Identifier parameters for the Port to ascertain whether this Port should be the Designated Port for the LAN to which it is attached.

(2) To test the value of the Bridge Identifier parameter conveyed in received Configuration BPDUs.

4.5.5.7 Designated Port. The Port Identifier of the Bridge Port believed to be the Designated Port for the LAN associated with the Port.

This parameter is used

(1) Together with the Designated Bridge and Port Identifier parameters for the Port to ascertain whether this Port should be the Designated Port for the LAN to which it is attached.

(2) By management to determine the topology of the Bridged Local Area Network.

4.5.5.8 Topology Change Acknowledge. The value of the Topology Change Acknowledgment flag in the next Configuration BPDU to be transmitted on the associated Port.

This parameter is used to record the need to set the Topology Change Acknowledgment flag in reply to a received Topology Change Notification BPDU.

4.5.5.9 Configuration Pending. A Boolean parameter set to record that a Configuration BPDU should be transmitted on expiry of the Hold Timer for the associated Port.

This parameter is used, in conjunction with the Hold Timer for the Port, to ensure that Configuration BPDUs are not transmitted too frequently, but that up-to-date information is transmitted.

4.5.6 Port Timers

4.5.6.1 Message Age Timer. This timer serves to measure the age of the received protocol information recorded for a Port, and to ensure that this information is discarded when its age exceeds the value of the Max Age parameter recorded by the Bridge.

The timeout value of the timer is that of the Bridge's Max Age parameter.

4.5.6.2 Forward Delay Timer. This timer serves to monitor the time spent by a Port in the Listening and Learning States.

The timeout value of the timer is that of the Bridge's Forward Delay parameter.

4.5.6.3 Hold Timer. This timer serves to ensure that Configuration BPDUs are not transmitted too frequently through any Bridge Port.

The timeout value of the timer is that of the Hold Time for the Bridge.

4.6 Elements of Procedure

4.6.1 Transmit Configuration BPDU

4.6.1.1 Purpose. To convey knowledge of the Designated Root, Root Path Cost, Designated Bridge, Designated Port, and the values of protocol timers to other Bridge Ports attached to the same LAN as the Port on which the Configuration BPDU is transmitted.

4.6.1.2 Use

4.6.1.2.1 As part of the Configuration BPDU Generation procedure (4.6.4).

4.6.1.2.2 As part of the Reply to Configuration BPDU procedure (4.6.5).

4.6.1.2.3 Following expiry of the Hold Timer for the Port (4.7.8) when the Configuration Pending flag parameter for the Port is set, as a consequence of a previous invocation of the procedure.

4.6.1.2.4 As part of the Acknowledge Topology Change procedure (4.6.16).

4.6.1.3 Procedure

4.6.1.3.1 If the Hold Timer for the Port is active then the Configuration Pending flag parameter for the Port shall be set.

4.6.1.3.2 Otherwise, if the Hold Timer is not active, a Configuration BPDU shall be transmitted through the selected Port within a time maximum BPDU transmission delay (as specified in 4.10.2) after any invocation of this procedure.

The Configuration BPDU shall have parameters set as follows:

(1) The Configuration BPDU Root Identifier parameter shall be set to the value of the Designated Root parameter held by the Bridge.

(2) The Configuration BPDU Root Path Cost parameter shall be set to the value of the Root Path Cost parameter held by the Bridge.

(3) The Configuration BPDU Bridge Identifier parameter shall be set to the value of the Bridge Identifier parameter held by the Bridge.

(4) The Configuration BPDU Port Identifier parameter shall be set to the value of the Port Identifier parameter held for the Bridge Port through which the Configuration BPDU is transmitted.

(5) If the Bridge has been selected as the Root, i.e., if the values of the Designated Root and Bridge Identifier parameters held by the Bridge are the same, the Message Age parameter of the Configuration BPDU shall be set to zero.

(6) Otherwise, the value of the Message Age parameter shall be set such that the transmitted Configuration BPDU does not convey an underestimate of the age of the Protocol Message received on the Root Port; i.e., the value transmitted shall be no less than that recorded by the Message Age Timer for that Port, shall be greater than the value received, and will incorporate any transmission delay. The value of the parameter shall not exceed its true value by more than the maximum Message Age increment overestimate as specified in 4.10.2.

(7) The Max Age, Hello Time, and Forward Delay parameters of the Configuration BPDU shall be set to the values of the Max Age, Hello Time, and Forward Delay parameters held for the Bridge.

(8) The Configuration BPDU Topology Change Acknowledgment flag parameter shall be set to the value of the Topology Change Acknowledge flag parameter for the Port. The Topology Change Acknowledge parameter is reset.

(9) The Configuration BPDU Topology Change flag parameter shall be set to the value of the Topology Change flag parameter for the Bridge.

(10) The Configuration Pending flag parameter for the Port is reset.

(11) The Hold Timer for the Port is started.

4.6.2 Record Configuration Information

4.6.2.1 Purpose. To record, for a Port, protocol parameters conveyed by a Configuration BPDU received on that Port.

4.6.2.2 Use. Following the receipt of a Configuration BPDU conveying protocol information that supersedes that already held, i.e., if

4.6.2.2.1 The Root Identifier denotes a Bridge of higher priority than that recorded as the Designated Root, or

4.6.2.2.2 The Root Identifier is the same as the Designated Root, and the Root Path Cost is lower than that recorded as the Designated Cost for the Port, or

4.6.2.2.3 The Root Identifier and Root Path Cost are as recorded for the Port, and the Bridge Identifier denotes a Bridge of higher priority than that recorded as the Designated Bridge for the Port, or

4.6.2.2.4 The Root Identifier and Root Path Cost are as recorded for the Port, and the Bridge Identifier is the same as that recorded as the Designated Bridge for the Port, and either

(1) The Bridge receiving the BPDU is not the Designated Bridge for the Port, or
(2) The Port Identifier denotes a Port of priority not less than that recorded as the Designated Port.

4.6.2.3 Procedure

4.6.2.3.1 The Designated Root, Designated Cost, Designated Bridge, and Designated Port parameters held for the Port are set to the values of the Root Identifier, Root Path Cost, Bridge Identifier, and Port Identifier parameters conveyed in the received Configuration BPDU.

4.6.2.3.2 The Message Age Timer for the Port is started, to run from the value of the Message Age parameter conveyed in the received Configuration BPDU.

4.6.3 Record Configuration Timeout Values

4.6.3.1 Purpose. To update the Max Age, Hello Time, Forward Delay, and Topology Change flag parameters to the latest values received from the Root.

4.6.3.2 Use. Following receipt of a Configuration BPDU on the Root Port which invokes the Record Configuration Information procedure (4.6.2.2).

4.6.3.3 Procedure. The Max Age, Hello Time, Forward Delay, and Topology Change parameters held by the Bridge are set to the values conveyed in the received Configuration BPDU.

4.6.4 Configuration BPDU Generation

4.6.4.1 Purpose. To convey to Bridges attached to each LAN for which the Bridge is Designated Bridge knowledge of the Designated Root, Root Path Cost, Designated Bridge, Designated Port, and the values of protocol timers.

4.6.4.2 Use

4.6.4.2.1 Following receipt of a Configuration BPDU on the Root Port which invokes the Record Configuration Information procedure (4.6.2.2).

4.6.4.2.2 Following expiry of the Hello Timer.

4.6.4.2.3 Following selection of the Bridge as the Designated Root by the Configuration Update procedure on expiry of a Message Age Timer for a Bridge Port.

4.6.4.2.4 Following selection of the Bridge as the Designated Root by management action.

4.6.4.3 Procedure. For each Port that is the Designated Port for the LAN to which it is attached (i.e., the value of the Designated Bridge and Designated Port parameters held for the Port are the same as that of the Bridge Identifier and the Port Identifier for that Port, respectively, which is not in the Disabled State), the Transmit Configuration BPDU procedure (4.6.1) is used.

4.6.5 Reply to Configuration BPDU

4.6.5.1 Purpose. To establish the Designated Bridge and Designated Port for a LAN in the case where another Bridge Port has transmitted a Configuration BPDU on that LAN. This arises if Configuration Messages from the current Root have not been received by the transmitting Bridge, either due to that Root having been newly established or to BPDU loss and subsequent expiry of a Message Age Timer.

4.6.5.2 Use. Following receipt of a Configuration BPDU on a Port which is the Designated Port for the LAN to which it is attached, which does not update the information held for that Port, i.e., does not satisfy the conditions (4.6.2.2) for the use of the Record Configuration Information procedure.

4.6.5.3 Procedure. The Transmit Configuration BPDU procedure (4.6.1) is used for the Port on which the Configuration BPDU was received.

4.6.6 Transmit Topology Change Notification BPDU

4.6.6.1 Purpose. To notify the Bridge on the path towards the Root that an extension of the topology has been detected by the transmitting Bridge. Eventually this will result in the Root being notified of the topology change.

4.6.6.2 Use

4.6.6.2.1 Following the detection or receipt of notification of a topology change by a Bridge that is not the Root.

4.6.6.2.2 Following expiry of the Topology Change Notification Timer.

4.6.6.3 Procedure. A Topology Change Notification BPDU shall be transmitted through the Root Port within a time of maximum BPDU transmission delay (4.10.2).

4.6.7 Configuration Update

4.6.7.1 Purpose. To update the configuration information held by the Bridge and the Bridge Ports.

4.6.7.2 Use

4.6.7.2.1 Following receipt of a Configuration BPDU which invokes the Record Configuration Information procedure (4.6.2.2).

4.6.7.2.2 Following a Port becoming the Designated Port for the LAN to which it is attached on expiry of the Message Age Timer for that Port.

4.6.7.2.3 Following a change in Port State through management action.

4.6.7.3 Procedure

4.6.7.3.1 The procedure for Root Selection (4.6.8) shall be used to select the Designated Root and the Root Port, and to calculate the Root Path Cost for this Bridge.

4.6.7.3.2 The procedure for Designated Port Selection (4.6.9) shall be used to determine for each Port whether the Port should become the Designated Port for the LAN to which it is attached.

4.6.8 Root Selection

4.6.8.1 Purpose. To select the Designated Root and the Root Port, and to calculate the Root Path Cost for this Bridge.

4.6.8.2 Use. This procedure is used by the Configuration Update procedure (4.6.7).

4.6.8.3 Procedure

4.6.8.3.1 The Root Port is set to identify the Port which; among those that are not the Designated Port for the LAN to which they are attached, are not Disabled, and have a Designated Root parameter of higher priority than the Bridge's Bridge Identifier;

(1) Has the highest priority Root associated with it, i.e., recorded as the Designated Root for the Port.

(2) Of two or more Ports with the highest priority Designated Root parameter, has the lowest Root Path Cost associated with it, i.e., the lowest sum of the Designated Cost and Path Cost parameters for any Port, or

(3) Of two or more Ports with the highest priority Designated Root parameter and lowest value of associated Root Path Cost, has the highest priority Bridge Identifier recorded as the Designated Bridge for the LAN to which the Port is attached, or
(4) Of two or more Ports with the highest priority Designated Root parameter, lowest value of associated Root Path Cost, and highest priority Designated Bridge, has the highest priority Port Identifier recorded as the Designated Port for the LAN to which the Port is attached, or
(5) Of two or more Ports with the highest priority Designated Root parameter, lowest value of associated Root Path Cost, and highest priority Designated Bridge and Designated Port, has the highest priority Port Identifier.

4.6.8.3.2 If there is no such Port, the value of the Root Port parameter is set to Zero, and
(1) The Designated Root parameter held by the Bridge is set to the Bridge Identifier parameter held for the Bridge, and
(2) The value of the Root Path Cost parameter held by the Bridge is set to zero.

4.6.8.3.3 Otherwise, i.e., if one of the Bridge Ports has been identified as the Root Port, then
(1) The Designated Root parameter held by the Bridge is set to the Designated Root parameter held for the Root Port, and
(2) The value of the Root Path Cost parameter held by the Bridge is set to the value of the Root Path Cost parameter associated with the Root Port, i.e., the sum of the values of the Path Cost and the Designated Cost parameters recorded for the Root Port.

4.6.9 Designated Port Selection

4.6.9.1 Purpose. To determine, for each Port, whether the Port should be the Designated Port for the LAN to which it is attached.

4.6.9.2 Use. As part of the Configuration Update procedure (4.6.7).

4.6.9.3 Procedure. The procedure to Become Designated Port (4.6.10) shall be invoked for each Port that

4.6.9.3.1 Has already been selected as the Designated Port for the LAN to which it is attached, i.e., the value of the Designated Bridge and Designated Port parameters held for the Port are the same as that of the Bridge Identifier and the Port Identifier for that Port respectively, or for which

4.6.9.3.2 The Designated Root parameter recorded for the Bridge differs from that recorded for the Port (note that this procedure follows root selection), or

4.6.9.3.3 The Bridge offers a Path of lower Cost to the Root for the LAN to which the Port is attached, i.e., the Root Path Cost recorded by the Bridge is less than the Designated Cost recorded for the Port, or

4.6.9.3.4 The Bridge offers a Path of equal Cost to the Root, and the Bridge's Bridge Identifier denotes a Bridge of higher priority than that recorded as the Designated Bridge for that Port, or

4.6.9.3.5 The Bridge offers a Path of equal Cost to the Root, and the Bridge is the Designated Bridge for the LAN to which the Port is attached, and the Port Identifier of the Port is of higher priority than that recorded as the Designated Port.

4.6.10 Become Designated Port

4.6.10.1 Purpose. Given that a Port is to be the Designated Port on the LAN to which it is attached, to assign appropriate values to those Port parameters that determine the active topology of the Bridged Local Area Network.

4.6.10.2 Use

4.6.10.2.1 Following expiry of the Message Age Timer for the Port.

4.6.10.2.2 Following selection of the Port as the Designated Port for the LAN to which it is attached by the Designated Port Selection procedure (4.6.9) as part of the Configuration Update procedure (4.6.7).

4.6.10.2.3 Following a change of Port State through management action (4.8.1, 4.8.2, 4.8.3, 4.8.5).

4.6.10.3 Procedure

4.6.10.3.1 The Designated Root parameter held for the Port is set to the value of the Designated Root parameter held by the Bridge.

4.6.10.3.2 The Designated Cost parameter held for the Port is set to the value of the Root Path Cost held by the Bridge.

4.6.10.3.3 The Designated Bridge parameter held for the Port is set to the Bridge Identifier of the Bridge.

4.6.10.3.4 The Designated Port parameter held for the Port is set to the Port Identifier of the Port.

4.6.11 Port State Selection

4.6.11.1 Purpose. To select the State of the Bridge's Ports based upon updated configuration information which indicates, for each Port, its part in the active topology of the Bridged Local Area Network, i.e., whether it should

(1) Be the Root Port for the Bridge.
(2) Be a Designated Port.
(3) Be a backup Port in a redundantly connected Bridged Local Area Network.

4.6.11.2 Use. Following use of the Configuration Update procedure after

4.6.11.2.1 Receipt of a Configuration BPDU conveying information that supersedes that recorded for a Port.

4.6.11.2.2 The expiry of the Message Age timer for a Port, which causes that Port to become the Designated Port for the LAN to which it is attached.

4.6.11.2.3 A change in the State of a Port arising through management action.

4.6.11.3 Procedure. For each of the Bridge's Ports:

4.6.11.3.1 If the Port is the Root Port for the Bridge, then

(1) The Configuration Pending flag parameter and Topology Change Acknowledge flag parameter for the Port are reset.
(2) The Make Forwarding procedure (4.6.12) is used for the Port.

4.6.11.3.2 Otherwise, if the Port is the Designated Port for the LAN to which it is attached, i.e., the Designated Bridge parameter for the Port is the same as the Bridge Identifier parameter held by the Bridge, and the Designated Port and Port Identifier parameters held for the Port are the same and the Port is not in the Disabled State, then

(1) The Message Age Timer for the Port is stopped, if running.
(2) The Make Forwarding procedure (4.6.12) is used for the Port.

4.6.11.3.3 Otherwise, if the Port is to be a backup Port, i.e., is neither the Root Port or a Designated Port, then

(1) The Configuration Pending flag parameter and Topology Change Acknowledge flag parameter for the Port are reset.
(2) The procedure to Make Blocking (4.6.13) is used.

4.6.12 Make Forwarding

4.6.12.1 Purpose. To permit a Port to participate in frame relay, following a suitable interval which ensures that temporary loops in the Bridged Local Area Network do not cause duplication of frames.

4.6.12.2 Use. As part of the Port State Selection procedure (4.6.11).

4.6.12.3 Procedure. If the Port State is Blocking, then

4.6.12.3.1 The Port State is set to Listening, and

4.6.12.3.2 The Forward Delay Timer for the Port is started.

4.6.13 Make Blocking

4.6.13.1 Purpose. To terminate the participation of a Port in frame relay.

4.6.13.2 Use. As part of the Port State Selection procedure (4.6.11).

4.6.13.3 Procedure. If the Port is not in the Disabled or the Blocking State, then

4.6.13.3.1 If the Port is in the Forwarding or Learning State, the Topology Change Detection procedure (4.6.14) is invoked.

4.6.13.3.2 The Port State for the Port is set to Blocking.

4.6.13.3.3 The Forward Delay Timer for the Port is stopped.

4.6.14 Topology Change Detection

4.6.14.1 Purpose. To record a topology change that has been detected by or notified to the Bridge. To initiate action to communicate the fact that a topology change has been detected to the Root.

4.6.14.2 Use

4.6.14.2.1 On receipt of a Topology Change Notification BPDU on a Port that is the Designated Port for the LAN to which it is attached.

4.6.14.2.2 When a Bridge Port is put into the Forwarding State following the expiry of the Forward Delay Timer for the Port, provided that the Bridge is the Designated Bridge for at least one of the LANs to which its Ports are attached.

4.6.14.2.3 When a Bridge Port in either the Forwarding or the Learning State is put into the Blocking State.

4.6.14.2.4 When the Bridge becomes the Root.

4.6.14.3 Procedure

4.6.14.3.1 If the Bridge has been selected as the Root, i.e., the Designated Root and Bridge Identifier parameters held for the Bridge are the same, then

(1) The Topology Change flag parameter held for the Bridge is set.
(2) The Topology Change Timer for the Bridge is started.

4.6.14.3.2 If the Bridge has not been selected as the Root and the Topology Change Detected flag parameter held for the Bridge is not already set, then

(1) The Transmit Topology Change Notification BPDU procedure (4.6.6) is invoked.
(2) The Topology Change Notification Timer is started.

4.6.14.3.3 The Topology Change Detected flag parameter for the Bridge is set.

4.6.15 Topology Change Acknowledged

4.6.15.1 Purpose. To terminate the transmission of Topology Change Notification BPDUs.

4.6.15.2 Use. Following receipt of a Configuration BPDU with the Topology Change Acknowledgment flag parameter set from the Designated Bridge for the LAN to which the Root Port is attached.

4.6.15.3 Procedure

4.6.15.3.1 The Topology Change Detected flag parameter held for the Bridge is reset.

4.6.15.3.2 The Topology Change Notification Timer is stopped.

4.6.16 Acknowledge Topology Change

4.6.16.1 Purpose. To acknowledge the notification of a detected topology change by another Bridge.

4.6.16.2 Use. Following receipt of a Topology Change Notification BPDU on a Port which is the Designated Port for the LAN to which it is attached.

4.6.16.3 Procedure

4.6.16.3.1 The Topology Change Acknowledge flag parameter for the Port is set.

4.6.16.3.2 The Transmit Configuration BPDU procedure (4.6.1) is used for the Port.

4.7 Operation of the Protocol. A Bridge Protocol Entity shall

(1) Communicate with its Peer Entities in other Bridges by the transmission of Bridge Protocol Data Units;
(2) Update stored protocol variables and timers;
(3) Change the State of the Bridge Ports;

following

(a) The reception of Bridge Protocol Data Units;
(b) The expiry of Bridge and Port Timers;

as required by the specification below (4.7.1, 4.7.2, 4.7.3, 4.7.4, 4.7.5, 4.7.6, 4.7.7, 4.7.8). In any case of ambiguity, reference shall be made to the Procedural Model (4.9), which constitutes the definitive description of the operation of the protocol.

This specification uses the Elements of Procedure of the Protocol described in 4.6, which, taken together with this subsection and the Protocol Parameters and Timers described in 4.5, provide an abstract description of the Spanning Tree Algorithm and Protocol. Conformance to this specification is achieved through maintenance of the Protocol Parameters and Timers and the transmission of BPDUs as described. Implementations are not otherwise constrained, in particular there is no conformance to individual elements of procedure.

4.7.1 Received Configuration BPDU

4.7.1.1 If the Configuration BPDU received conveys protocol information that supersedes that already held for a Port as specified in 4.6.2.2, then the following sequence of Procedures is used:

4.7.1.1.1 The Record Configuration Information procedure (4.6.2).

4.7.1.1.2 The Configuration Update procedure (4.6.7).

4.7.1.1.3 The Port State Selection procedure (4.6.11).

4.7.1.1.4 If the Bridge was selected as the Root prior to Configuration Update, but is no longer, then the Hello Timer (4.5.4.1) is stopped.

4.7.1.1.5 If the Bridge was selected as the Root prior to Configuration Update, but is no longer, and the Topology Change Detected flag parameter is set, then the Topology Change Timer is stopped, the Transmit Topology Change Notification BPDU procedure (4.6.6) is used, and the Topology Change Notification Timer is started.

4.7.1.1.6 If the Configuration BPDU was received on the Root Port (i.e., the Port selected as the Root Port by the Configuration Update procedure), the Record Configuration Timeout Values (4.6.3) and the Configuration BPDU Generation (4.6.4) procedures.

4.7.1.1.7 If the Configuration BPDU was received on the Root Port and the Topology Change Acknowledgment flag parameter was set, the Topology Change Acknowledged procedure (4.6.15).

4.7.1.2 If the Configuration BPDU received does not convey information superseding that already held for the Port and that Port is the Designated Port for the LAN to which it is attached, i.e., the value of the Designated Bridge and Designated Port parameters held for the Port are the same as that of the Bridge Identifier for the Bridge and the Port Identifier for that Port respectively, then

4.7.1.2.1 The Reply to Configuration BPDU procedure (4.6.5) is used.

4.7.2 Received Topology Change Notification BPDU. If the Port on which the Topology Change Notification BPDU was received is the Designated Port for the LAN to which it is attached, then

4.7.2.1 The Topology Change Detection procedure (4.6.14) is used.

4.7.2.2 The Acknowledge Topology Change procedure (4.6.16) is used.

4.7.3 Hello Timer Expiry. The Configuration BPDU Generation procedure (4.6.4) is used and the Hello Timer (4.5.4.1) is started.

4.7.4 Message Age Timer Expiry

4.7.4.1 The procedure to Become Designated Port (4.6.10) is used for the Port for which Message Age Timer has expired.

4.7.4.2 The Configuration Update procedure (4.6.7) is used.

4.7.4.3 The Port State Selection procedure (4.6.11) is used.

4.7.4.4 If the Bridge is selected as the Root following Configuration Update, then

4.7.4.4.1 The Max Age, Hello Time, and Forward Delay parameters held by the Bridge are set to the values of the Bridge Max Age, Bridge Hello Time, and Bridge Forward Delay parameters.

4.7.4.4.2 The Topology Change Detection procedure (4.6.14) is used.

4.7.4.4.3 The Topology Change Notification Timer (4.5.4.2) is stopped.

4.7.4.4.4 The Configuration BPDU Generation procedure (4.6.4) is used and the Hello Timer is started.

4.7.5 Forward Delay Timer Expiry

4.7.5.1 If the State of the Port for which the Forward Delay Timer (4.5.6.2) has expired was Listening, then

4.7.5.1.1 The Port State is set to Learning, and

4.7.5.1.2 The Forward Delay Timer is restarted.

4.7.5.2 Otherwise, if the State of the Port for which the Forward Delay Timer (4.5.6.2) has expired was Learning, then

4.7.5.2.1 The Port State is set to Forwarding, and

4.7.5.2.2 If the Bridge is the Designated Bridge for at least one of the LANs to which its Ports are attached, the Topology Change Detection procedure (4.6.14) is invoked.

4.7.6 Topology Change Notification Timer Expiry

4.7.6.1 The Transmit Topology Change Notification BPDU procedure (4.6.6) is used.

4.7.6.2 The Topology Change Notification Timer (4.5.4.2) is restarted.

4.7.7 Topology Change Timer Expiry

4.7.7.1 The Topology Change Detected flag parameter held by the Bridge is reset.

4.7.7.2 The Topology Change flag parameter held by the Bridge is reset.

4.7.8 Hold Timer Expiry. If the Configuration Pending flag parameter for the Port for which the Hold Timer (4.5.6.3) has expired is set, the Transmit Configuration BPDU procedure (4.6.1) is invoked for that Port.

4.8 Management of the Bridge Protocol Entity. Management control of the Bridge Protocol Entity, which operates the Spanning Tree Algorithm and Protocol, may be exerted in order to

(1) Meet any requirements for local information and configuration services.
(2) Support management operations.

This section specifies the interaction of the following management operations with the parameters and procedures of the Spanning Tree Algorithm and Protocol:

(a) Initialization
(b) Enabling an individual Port
(c) Disabling an individual Port
(d) Changing the priority part of a Bridge Identifier
(e) Changing the priority part of a Port Identifier
(f) Change the Path Cost associated with an individual Port

These operations shall modify the Protocol Parameters and Timers and transmit BPDUs as described below (4.8.1, 4.8.2, 4.8.3, 4.8.4, 4.8.5, 4.8.6). Implementations are not otherwise constrained; in particular, there is no conformance to individual elements of procedure. In any case of ambiguity, reference shall be made to the Procedural Model (4.9), which constitutes the definitive description of these operations.

This section does not specify which operations are made available to a remote management station, nor how these are combined and conveyed. Operations and facilities that can be provided by remote management are detailed in Section 6. Similarly, this section does not specify the availability of local information and configuration procedures.

4.8.1 Initialization

4.8.1.1 The Designated Root parameter held for the Bridge is set equal to the

value of the Bridge Identifier, and the value of the Root Path Cost parameter held for the Bridge is set to zero.

4.8.1.2 The Max Age, Hello Time, and Forward Delay parameters held by the Bridge are set to the values of the Bridge Max Age, Bridge Hello Time, and Bridge Forward Delay parameters.

4.8.1.3 The Topology Change Detected and Topology Change flag parameters for the Bridge are reset, and the Topology Change Notification Timer (4.5.4.2) and Topology Change Timer (4.5.4.3) are stopped, if running.

4.8.1.4 For each of the Bridge's Ports

4.8.1.4.1 The Become Designated Port procedure (4.6.10) is used to assign values to the Designated Root, Designated Cost, Designated Bridge, and Designated Port parameters for the Port.

4.8.1.4.2 The Port State is set to Blocking if the Port is to be enabled following initialization; alternatively, the Port State is set to Disabled.

4.8.1.4.3 The Topology Change Acknowledge flag parameter is reset.

4.8.1.4.4 The Configuration Pending flag parameter is reset.

4.8.1.4.5 The Message Age Timer (4.5.6.1) is stopped, if running.

4.8.1.4.6 The Forward Delay Timer (4.5.6.2) is stopped, if running.

4.8.1.4.7 The Hold Timer (4.5.6.3) is stopped, if running.

4.8.1.5 The Port State Selection procedure (4.6.11) is used to select the State of each of the Bridge's Ports.

4.8.1.6 The Configuration BPDU Generation procedure (4.6.4) is invoked and the Hello Timer (4.5.4.1) started.

4.8.2 Enable Port

4.8.2.1 The Become Designated Port procedure (4.6.10) is used to assign values to the Designated Root, Designated Cost, Designated Bridge, and Designated Port parameters for the Port.

4.8.2.2 The Port State is set to Blocking.

4.8.2.3 The Topology Change Acknowledge flag parameter is reset.

4.8.2.4 The Configuration Pending flag parameter is reset.

4.8.2.5 The Message Age Timer (4.5.6.1) is stopped, if running.

4.8.2.6 The Forward Delay Timer (4.5.6.2) is stopped, if running.

4.8.2.7 The Hold Timer (4.5.6.3) is stopped, if running.

4.8.2.8 The Port State Selection procedure (4.6.11) is used.

4.8.3 Disable Port

4.8.3.1 The Become Designated Port procedure (4.6.10) is used to assign values to the Designated Root, Designated Cost, Designated Bridge, and Designated Port parameters for the Port.

4.8.3.2 The Port State is set to Disabled.

4.8.3.3 The Topology Change Acknowledge flag parameter is reset.

4.8.3.4 The Configuration Pending flag parameter is reset.

4.8.3.5 The Message Age Timer (4.5.6.1) is stopped, if running.

4.8.3.6 The Forward Delay Timer (4.5.6.2) is stopped, if running.

4.8.3.7 The Configuration Update procedure (4.6.7) is used.

4.8.3.8 The Port State Selection procedure (4.6.11) is used.

4.8.3.9 If the Bridge has been selected as the Root following Configuration Update, then

4.8.3.9.1 The Max Age, Hello Time, and Forward Delay parameters held by the Bridge are set to the values of the Bridge Max Age, Bridge Hello Time, and Bridge Forward Delay parameters.

4.8.3.9.2 The Topology Change Detection procedure (4.6.14) is used.

4.8.3.9.3 The Topology Change Notification Timer (4.5.4.2) is stopped.

4.8.3.9.4 The Configuration BPDU Generation procedure (4.6.4) is used and the Hello Timer is started.

4.8.4 Set Bridge Priority

4.8.4.1 The new value of the Bridge Identifier is calculated.

4.8.4.2 The value of the Designated Bridge parameter held for each Port that has been selected as the Designated Port for the LAN to which it is attached; i.e., for which the value of the Designated Bridge and Designated Port parameters were the same as that of the Bridge Identifier and the Port Identifier for that Port, respectively; is set to the new value of the Bridge Identifier.

4.8.4.3 The Bridge Identifier parameter held by the Bridge is set to the new value.

4.8.4.4 The Configuration Update procedure (4.6.7) is used.

4.8.4.5 The Port State Selection procedure (4.6.11) is used.

4.8.4.6 If the Bridge has been selected as the Root following Configuration Update, then

4.8.4.6.1 The Max Age, Hello Time, and Forward Delay parameters held by the Bridge are set to the values of the Bridge Max Age, Bridge Hello Time, and Bridge Forward Delay parameters.

4.8.4.6.2 The Topology Change Detection procedure (4.6.14) is used.

4.8.4.6.3 The Topology Change Notification Timer (4.5.4.2) is stopped.

4.8.4.6.4 The Configuration BPDU Generation procedure (4.6.4) is used and the Hello Timer is started.

4.8.5 Set Port Priority

4.8.5.1 The new value of the Port Identifier is calculated.

4.8.5.2 If the Port has been selected as the Designated Port for the LAN to which it is attached; i.e., the value of the Designated Bridge and Designated Port parameters were the same as that of the Bridge Identifier and the Port Identifier, respectively; the Designated Port parameter held for the Port is set to the new value of the Port Identifier.

4.8.5.3 The Port Identifier parameter held for the Port is set to the new value.

4.8.5.4 If the value of the Designated Bridge parameter held for the Port is equal to that of the Bridge's Bridge Identifier, and the new value of the Port Identifier is of higher priority than that recorded as the Designated Port, then

4.8.5.4.1 The Become Designated Port procedure (4.6.10) is used to assign values to the Designated Root, Designated Cost, Designated Bridge, and Designated Port parameters for the Port.

4.8.5.4.2 The Port State Selection procedure (4.6.11) is used.

4.8.6 Set Path Cost

4.8.6.1 The Path Cost parameter for the Port is set to the new value.

4.8.6.2 The Configuration Update procedure (4.6.7) is used.

4.8.6.3 The Port State Selection procedure is used.

4.9 Procedural Model. This subsection constitutes the definitive description of the operation of the Spanning Tree Algorithm and Protocol. The natural language text in 4.6, 4.7, and 4.8 of this standard is intended to informally present the semantics of operation specified here. Should differences of interpretation exist between that text and this procedural model, the latter shall take precedence.

4.9.1 Overview. The parameters, timers, elements of procedure, and operation of the protocol are presented below as a compilable program in the computer language C (ANSI X3.159 [1]).

The objective of presenting this program is to precisely and unambiguously specify the operation of the algorithm and protocol. The description of the operation of the protocol in a computer language is in no way intended to constrain the implementation of the protocol; a real implementation may employ any appropriate technology.

Conformance of equipment to this standard is purely in respect of observable protocol. The program contained in this section contains modeling details that are of local concern to an implementation; there is no conformance in respect of these details.

The natural language text in 4.6, 4.7, 4.8 follows the computer language text contained in this section. In order to preserve the compactness of the program text, all comments are made by reference to the natural language description and are of the form 4.n.n.n. Where a program statement invokes an element of procedure, a further reference is made to the particular condition, of those listed for the procedure, that has caused the procedure to be invoked.

4.10 Performance. This section places requirements on the performance of the Bridges in a Bridged Local Area Network and on the setting of the parameters of the Spanning Tree Algorithm and Protocol. These are necessary to ensure that the algorithm and protocol operate correctly.

It recommends default operational values for performance parameters. These have been specified in order to avoid the need to set values prior to operation, and have been chosen with a view to maximizing the ease with which Bridged Local Area Network components interoperate.

It specifies absolute maximum values for performance parameters. The ranges of applicable values are specified to assist in the choice of operational values and to provide guidance to implementors.

4.10.1 Requirements. For correct operation, the parameters and configuration of Bridges in the Bridged Local Area Network ensure that

(1) Bridges do not initiate reconfiguration if none is needed. This means that a Bridge Protocol Message is not timed out before its successor arrives, unless a failure has occurred.

(2) Following reconfiguration frames are not forwarded on the new active topology, while frames that were initially forwarded on the previous active topology are still in the Bridged Local Area Network. This ensures that frames are not duplicated.

These requirements are met through placing restrictions on

(a) The **maximum bridge diameter** of the Bridge Local Area Network, the maximum number of Bridges between any two points of attachment of end stations.

(b) The **maximum bridge transit delay**, the maximum time elapsing between reception and transmission by a Bridge of a forwarded frame, frames that would otherwise exceed this limit being discarded.

(c) The **maximum BPDU transmission delay**, the maximum delay prior to the transmission of a Bridge Protocol Data Unit following the need to transmit such a BPDU arising, as specified in 4.7.

(d) The **maximum Message Age increment overestimate** that may be made to the value of the Message Age parameter in transmitted BPDUs or to the age of stored Bridge Protocol Message information.

(e) The values of the **Bridge Hello Time**, **Bridge Max Age**, **Bridge Forward Delay**, and **Hold Time** parameters.

Additionally a Bridge shall not

(i) Underestimate the increment to the Message Age parameter in transmitted BPDUs.

(ii) Underestimate Forward Delay.

(iii) Overestimate the Hello Time interval when acting as the Root.

4.10.2 Parameter Values. Recommended default, absolute maximum, and ranges of parameters are specified in Tables 4-1, 4-2, 4-3, 4-4, and 4-5.

A Bridge shall not exceed the absolute maximum values specified in Table 4-2 for **maximum bridge transit delay**, **maximum BPDU transmission delay** and **maximum Message Age increment overestimate**.

Table 4-1
Maximum Bridge Diameter

Parameter	Recommended Value
maximum bridge diameter	7

Table 4-2
Transit and Transmission Delays

Parameter	Recommended Value	Absolute Maximum
maximum bridge transit delay	1.0	4.0
maximum BPDU transmission delay	1.0	4.0
maximum Message Age increment overestimate	1.0	4.0

All times are in seconds.

Table 4-3
Spanning Tree Algorithm Timer Values

Parameter	Recommended or Default Value	Fixed Value	Range
Bridge Hello Time	2.0	—	1.0 – 10.0
Bridge Max Age	20.0	—	6.0 – 40.0
Bridge Forward Delay	15.0	—	4.0 – 30.0
Hold Time	—	1.0	—

All times are in seconds.
— Not applicable.
4.10.2 constrains the relationship between Bridge Max Age and Bridge Forward Delay.

Table 4-4
Bridge and Port Priority Parameter Values

Parameter	Recommended or Default Value	Range
Bridge Priority	32768	0 – 65535
Port Priority	128	0 – 255

Table 4-5
Path Cost Parameter Values

Parameter	Recommended Value	Absolute Minimum	Range
Path Cost	see 4.10.2	1	1 – 65535

If the values of **Bridge Hello Time**, **Bridge Max Age**, and **Bridge Forward Delay** can be set by management, the Bridge shall have the capability to use the full range of values in the parameter ranges specified in Table 4-3, with a granularity of 1 second.

A Bridge shall use the value of **Hold Time** shown in Table 4-3.

A Bridge shall enforce the following relationships:

$$2 \times (Bridge\_Forward\_Delay - 1.0\ seconds) \geq Bridge\_Max\_Age$$

$$Bridge\_Max\_Age \geq 2 \times (Bridge\_Hello\_Time + 1.0\ seconds)$$

It is recommended that default values of the **Path Cost** parameter for each Bridge Port be based on the following formula:

$$Path\_Cost = 1000/Attached\_LAN\_speed\_in\_Mb/s$$

which gives a default value for **Path Cost** of 100 for a 10 Mb/s LAN.

If the values of the **Bridge Priority** and the **Port Priority** for each of the Ports can be set by management, the Bridge shall have the capability to use the full range of values in the parameter ranges specified in Table 4-4, with a granularity of 1.

A Bridge shall not use a lower value for the **Path Cost** parameter associated with any Port than the absolute minimum value specified in Table 4-5.

If the value of **Path Cost** can be set by management, the Bridge shall have the capability to use the full range of values in the parameter ranges specified in Table 4-5, with a granularity of 1.